Science Standards of Learning

Teacher Resource Guide

Earth Science

Commonwealth of Virginia
Department of Education
Richmond, Virginia
2000

Standard ES.1 a, b

The student will plan and conduct investigations in which

- volume, area, mass, elapsed time, direction, temperature, pressure, distance, density, and changes in elevation/depth are calculated utilizing the most appropriate tools; and
- technologies, including computers, are used to collect, analyze, and report data and to demonstrate concepts and simulate experimental conditions.

Essential Understandings	Essential Knowledge and Skills
Density expresses the relationship between mass and volume.	Skills · Measure mass and volume of materials in the lab. · Calculate density. · Interpret data from a graph or table that shows change in mass, density, or temperature with time. · Interpret data from a graph or table that shows changes with temperature or pressure with depth.

Standard ES.1 c, d, e

The student will plan and conduct investigations in which

- scales, diagrams, maps, charts, graphs, tables, and profiles are constructed and interpreted;
- variables are manipulated with repeated trials; and
- a scientific viewpoint is constructed and defended.

Essential Understandings	Essential Knowledge and Skills
· Information and data collected can be organized and expressed in the form of charts, graphs, and diagrams. · Changing relevant variables will generally change the outcome. · A hypothesis can be supported, modified, or rejected based on collected data. · Experiments are designed to test hypotheses.	Skills · Compare topographic maps of different scales. · Construct a graph, table, chart, and/or diagram from data. · Interpret graphs and diagrams. · Use the scientific method to design and test a hypothesis.

Standard ES.2 a, b, c, d, e, f

The student demonstrates scientific reasoning and logic by

- analyzing how science explains and predicts the interactions and dynamics of complex Earth systems;
- recognizing that evidence is required to evaluate hypotheses and explanations;
- comparing different scientific explanations for the same observations about the Earth;
- explaining that observation and logic are essential for reaching a conclusion;
- evaluating evidence for scientific theories related to plate tectonics, the structure of the Earth, and its ancient age and origin; and
- making informed judgments related to resource use and its effects on Earth systems.

Essential Understandings	Essential Knowledge and Skills
· The Earth is a dynamic system and all atmospheric, geological, and oceanographic processes interrelate and influence one another. · Conclusions are only as good as the quality of the collected data. · Any valid hypothesis can be tested. · Any valid scientific theory has passed tests designed to invalidate it. · A hypothesis can be supported, modified, or rejected based on collected data. · Experiments are designed to test hypotheses. · There can be more than one explanation for any phenomena.	<u>Skills</u> · Make predictions using scientific data and data analysis. · Use data to support or reject a hypothesis. · Explain how the scientific method is used to validate scientific theories.

Standard ES.3 a, b, c, d

The student will investigate and understand how to read and interpret maps, globes, models, charts, and imagery. Key concepts include

- maps (bathymetric, geologic, topographic, and weather) and star charts;
- imagery (aerial photography and satellite images);
- direction and distance measurements on any map or globe; and
- location by latitude and longitude and topographic profiles.

Essential Understandings	Essential Knowledge and Skills
· Scale relates to actual distance. · Topographic maps, air photos, and satellite images relate to actual 3-D landforms. · Grid systems are used to define locations and directions on maps, globes, and charts.	<u>Skills</u> · Read and interpret maps, including legends and lines (e.g., contour and isobar) used on maps. · Locate points and directions on maps and globes using latitude and longitude. · Construct profiles from topographic contours. · Determine distance and elevation on a map. · Identify a hilltop, stream, and valley on a topographic map.

Standard ES.4 a

The student will investigate and understand the characteristics of the Earth including

- plate tectonics.

Essential Understandings	Essential Knowledge and Skills
· The core, mantle, and crust of the Earth are dynamic systems, constantly in motion. · The Earth's lithosphere is divided into plates that are in motion with respect to one another. · Most geologic activity (e.g., earthquakes, volcanoes, and mountain building) occurs as a result of relative motion along plate boundaries. · Plate motion occurs as a consequence of convection in the mantle. · There are two different types of crust (oceanic and continental) that have very different characteristics.	<u>Knowledge</u> · The Earth consists of a solid, mostly iron inner core; a liquid, mostly iron outer core; a rocky, plastic mantle; and a rocky, brittle crust. · The lithosphere is the solid outer shell of Earth. · Relative plate motions and plate boundaries are convergent (subduction and continental collision), divergent (sea-floor spreading), or transform. · Earthquake activity is associated with all plate boundaries. · Major features of convergent boundaries include collision zones (folded and thrust-faulted mountains) and subduction zones (volcanoes and trenches). · Major features of divergent boundaries include mid-ocean ridges, rift valleys, and volcanoes. · Major features of transform boundaries include strike-slip faults.

Standard ES.4 a (continued)

Essential Understandings	Essential Knowledge and Skills
	· Ocean crust is relatively thin, young and dense. · Continental crust is relatively thick, old, and less dense. · Continental drift is a consequence of plate tectonics. · Hot spot volcanic activity is exceptional in that it is not related to plate boundaries.

Standard ES.4 b, d

The student will investigate and understand the characteristics of the Earth including

- water in all three states; and
- effects of density differences and energy transfer on the activities of the atmosphere, oceans, and Earth's interior.

Essential Understandings	Essential Knowledge and Skills
· Water occurs on earth as a solid (ice), a liquid, or a gas (water vapor). · Temperature differences produce differences in density, which produces convection.	<u>Knowledge</u> · Convection is a current that is set up when hot, less dense material rises, cools, becomes denser, and sinks. · Convection is the major mechanism of energy transfer in the oceans, atmosphere, and Earth's interior. · Convection in the atmosphere is a major cause of weather. · Plate tectonics is driven by convection in the Earth's mantle. · Some ocean currents are convection currents.

Standard ES.4 c

The student will investigate and understand the characteristics of the Earth including

- position of the Earth in the solar system.

Essential Understandings	Essential Knowledge and Skills
The Earth is one of nine planets in the solar system.	Knowledge The Earth is the third planet from the sun.

Standard ES.5 a, b

The student will investigate and understand how to identify major rock-forming and ore minerals based on physical and chemical properties. Key concepts include

- properties including hardness, color and streak, luster, cleavage, fracture, and unique properties; and
- use of minerals.

Essential Understandings	Essential Knowledge and Skills
· There is a difference between rocks and minerals. · Minerals can be identified based on specific chemical and physical properties. · Minerals are important to human wealth and welfare.	<u>Knowledge</u> · A mineral is a naturally-occurring, inorganic, solid substance with a definite chemical composition and structure. · Minerals may be identified by their physical properties such as hardness, color, luster, and streak. · Most rocks are made of one or more minerals. · Some major rock-forming minerals are quartz, feldspar, calcite, and mica. · Ore minerals include pyrite, magnetite, hematite, galena, halite, graphite, and sulfur.

Standard ES.6 a, b, c

The student will investigate and understand how to identify common rock types based on mineral composition and textures and the rock cycle as it related to the transformation of rock types. Key concepts include

- igneous (intrusive and extrusive);
- sedimentary (clastic and chemical); and
- metamorphic (foliated and unfoliated) rocks.

Essential Understandings	Essential Knowledge and Skills
· Rocks can be identified on the basis of mineral content and texture. · The three major groups of rocks are defined by the processes by which they are formed. · The rock cycle describes the processes by which one type of rock can be changed into another type of rock.	<u>Knowledge</u> · Igneous rock forms from molten rock that cools and hardens either below or on the Earth's surface. · Sedimentary rocks form from rock fragments or organic matter bound together, or are formed by chemical precipitation. · Metamorphic rocks form by the effects of heat, pressure, or chemical action on other rocks. · Extrusive igneous rocks have small crystals and a fine-grained texture. · Intrusive igneous rocks have larger crystals and a coarse-grained texture. · Extrusive igneous rocks include pumice, obsidian, and basalt.

Standard ES.6 a, b, c (continued)

Essential Understandings	Essential Knowledge and Skills
	· Intrusive igneous rocks include granite. · Sedimentary rocks are clastic or nonclastic. · Clastic sedimentary rocks are made up of fragments of other rocks and include sandstone, conglomerate, and shale. · Non-clastic sedimentary rocks include limestone and gypsum. · Metamorphic rocks can be foliated or unfoliated. · Foliated metamorphic rocks have fine layers and include slate, schist, and gneiss. · Unfoliated metamorphic rocks have few or no layers and include marble and quartzite. <u>Skills</u> · Interpret the rock cycle diagram. · Classify the following rock types as igneous, metamorphic, or sedimentary: pumice, obsidian, basalt, granite, sandstone, conglomerate, shale, limestone, gypsum, slate, schist, gneiss, marble, and quartzite.

Standard ES.7 a, b, c, d, e

The student will investigate and understand the difference between renewable and nonrenewable resources. Key concepts include

- fossil fuels, minerals, rocks, water, and vegetation;
- advantages and disadvantages of various energy sources;
- resources found in Virginia;
- use of resources and their effects on standards of living; and
- environmental cost and benefits.

Essential Understandings	Essential Knowledge and Skills
· All resources are limited and either renewable or non-renewable. · There are advantages and disadvantages to using any energy source. · Virginia has many natural resources. · Modern living standards are supported by extensive use of both renewable and non-renewable resources. · Extraction and use of any resource carries an environmental cost that must be weighed against economic benefit.	<u>Knowledge</u> · Renewable resources can be replaced by nature at a rate close to the rate at which they are used. · Renewable resources include vegetation, sunlight, and surface water. · Non-renewable resources are renewed very slowly or not at all. · Non-renewable resources include coal, oil, and minerals. · Fossil fuels are non-renewable and cause pollution, but they are relatively cheap and easy to use. · Major Virginia rock and mineral resources include coal for energy, gravel and crushed stone for road construction, and limestone for making concrete. Virginia also has newly discovered deposits of titanium.

Standard ES.8 a

The student will investigate and understand geological processes including plate tectonics. Key concepts include

- how geologic processes are evidenced in the physiographic provinces of Virginia including the Coastal Plan, Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateau.

Essential Understandings	Essential Knowledge and Skills
· Virginia has a billion-year long tectonic and geologic history. · Virginia has five physiographic provinces produced by past tectonic and geologic activity. · Each province has unique physical characteristics resulting from its geologic past. · Geologic processes produce characteristic structures and features.	<u>Knowledge</u> · The five physiographic provinces are Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateau. · The Coastal Plain is a flat area underlain by young, unconsolidated sediments. These layers of sediment were produced by erosion of the Appalachian Mountains and then deposited on the Coastal Plain. · The Piedmont is an area of rolling hills underlain by mostly ancient igneous and metamorphic rocks. The igneous rocks are the roots of volcanoes formed during an ancient episode of subduction that occurred before the formation of the Appalachian Mountains. · The Blue Ridge is a high ridge separating the Piedmont from the Valley and Ridge Province. The billion-year old igneous and metamorphic rocks of the Blue Ridge

Standard ES.8 a (continued)

Essential Understandings	Essential Knowledge and Skills
	are the oldest in the state. Some metamorphism of these rocks occurred during the formation of the Appalachian Mountains. · The Valley and Ridge province is an area with long parallel ridges and valleys underlain by ancient folded and faulted sedimentary rocks. The folding and faulting of the sedimentary rocks occurred during a collision between Africa and North America. The collision, which occurred in the late Paleozoic, produced the Appalachian Mountains. · The Appalachian Plateau has rugged irregular topography and is underlain by ancient, flat-lying sedimentary rocks. The area is actually a series of plateaus separated by faults. Most of Virginia's coal resources are found in the plateau province. <u>Skills</u> Label a map of the physiographic provinces of Virginia.

Standard ES.8 b, c

The student will investigate and understand geological processes including plate tectonics. Key concepts include

- processes (faulting, folding, volcanism, metamorphism, weathering, erosion, deposition, and sedimentation) and their resulting features: and
- tectonic processes (subduction, rifting and seafloor spreading, and continental collision).

Essential Understandings	Essential Knowledge and Skills
There is a relationship among weathering, erosion, and deposition.	<u>Knowledge</u> · A fault is a break or crack in the Earth's crust along which movement has occurred. · Most active faults are located at or near plate boundaries. Earthquakes result when movement occurs along a fault. · When rocks are compressed horizontally, their layers may be deformed into wave-like forms called folds. This commonly occurs during continental collisions. · A volcano is an opening where magma is erupted onto the Earth's surface. Most volcanic activity is associated with subduction, rifting or sea-floor spreading. · Weathering is the process by which rocks are broken down by the action of water, air, and organisms. · Erosion is the process by which earth materials are transported by moving water, ice, or wind.

Standard ES.8 b, c (continued)

Essential Understandings	Essential Knowledge and Skills
	· Deposition is the process by which Earth materials carried by wind, water, or ice settle out and are deposited. · Weathering accelerates erosion and thus increases the rate of deposition. · The potential for erosion is greatest in areas of high relief. · The potential for deposition is greatest in areas of low relief, especially standing water, and particularly the ocean.

Standard ES.9 a, b

The student will investigate and understand how freshwater resources are influenced by geological processes and activities of humans. Key concepts include

- processes of soil development; and
- development of karst topography.

Essential Understandings	Essential Knowledge and Skills
· Soil is formed by the weathering of rocks and organic activity. · Karst topography is developed in areas underlain by carbonate rocks including limestone.	<u>Knowledge</u> · Soil is loose rock fragments and clay derived from weathered rock mixed with organic material. · Karst topography includes features like caves and sinkholes. · Karst topography forms when limestone is slowly dissolved away by slightly acidic groundwater. · Where limestone is abundant in the Valley and Ridge province of Virginia, karst topography is common.

Standard ES.9 c, d, e

The student will investigate and understand how freshwater resources are influenced by geological processes and the activities of humans. Key concepts include

- identification of groundwater zones including water table, zone of saturation, and zone of aeration;
- identification of other sources of freshwater including aquifers with reference to the hydrologic cycle; and
- dependence on freshwater resources and the effects of human usage on water quality.

Essential Understandings	Essential Knowledge and Skills
· A substantial amount of water is stored in permeable soil and rock underground. · The Earth's fresh water supply is finite. · Water is continuously being passed through the hydrologic cycle. · Fresh water is necessary for survival and most human activities.	<u>Knowledge</u> · Permeability is a measure of the ability of a rock or sediment to transmit water or other liquids. · Water does not easily pass through impermeable materials. · Geological processes, such as erosion, and human activities, such as waste disposal, can pollute water supplies. <u>Skills</u> · Interpret a simple groundwater diagram showing the zone of aeration, the zone of saturation, the water table, and an aquifer. · Interpret a simple hydrologic cycle diagram, including evaporation, condensation, precipitation, and runoff.

Standard ES.10 a, d

The student will investigate and understand that many aspects of the history and evolution of the Earth and life can be inferred by studying rocks and fossils. Key concepts include

- traces of remains of ancient, often extinct life are preserved by various means in many sedimentary rocks; and
- rocks and fossils from many different geologic periods and epochs are found in Virginia.

Essential Understandings	Essential Knowledge and Skills
· Evidence of ancient, often extinct life is preserved in many sedimentary rocks. · Fossil evidence indicates that life has changed and become more complex over geologic time.	<u>Knowledge</u> · A fossil is the remains, impressions, or other evidence of the former existence of life preserved in rock. · Some ways in which fossils can be preserved are molds, casts, and original bone or shell. · Almost all fossils are found in sedimentary rocks. · In Virginia, fossils are found mainly in the Coastal Plain, Valley and Ridge, and Appalachian Plateau provinces. · Most Virginia fossils are of marine organisms. This indicates that large areas of the state have been periodically covered by seawater. · Paleozoic, Mesozoic, and Cenozoic fossils are found in Virginia. <u>Skills</u> Describe how life has changed and become more complex over geologic time.

Standard ES.10 b, c

The student will investigate and understand that many aspects of the history and evolution of the Earth and life can be inferred by studying rocks and fossils. Key concepts include

- superposition, cross-cutting relationships, and radioactive decay are methods of dating bodies of rock; and
- absolute and relative dating have different applications but can be used together to determine the age of rocks and structures.

Essential Understandings	Essential Knowledge and Skills
· The Earth is very ancient, about 4.6 billion years old. · The history of the Earth and the ages of rocks can be investigated and understood by studying rocks and fossils.	Knowledge · Relative time places events in a sequence without assigning any numerical ages. · Fossils, superposition, and cross-cutting relations are used to determine the relative ages of rocks. · Absolute time places a numerical age on an event. · Radioactive decay is used to determine the absolute age of rocks. Skills Interpret a simple geologic history diagram using superposition and cross-cutting relations.

Standard ES.11 a

The student will investigate and understand that oceans are complex, interactive physical, chemical, and biological systems and are subject to long- and short-term variations. Key concepts include

- physical and chemical changes (tides, waves, currents, sea level and ice cap variations, upwelling, and salinity concentrations).

Essential Understandings	Essential Knowledge and Skills
The ocean is a dynamic system in which many chemical and physical changes are taking place.	<u>Knowledge</u> · The tides are the daily, periodic rise and fall of water level caused by the gravitational pull of the sun and moon. · Most waves on the ocean surface are generated by wind. · There are large current systems in the oceans that carry warm water towards the poles and cold water towards the equator. · Sea level falls when glacial ice caps grow and rises when the ice caps melt. · Upwellings bring cold, nutrient-rich water from the deep ocean to the surface and are areas of rich biological activity. · Estuaries, like the Chesapeake Bay, are areas where fresh and salt water mix, producing variations in salinity and high biological activity.

Standard ES.11 b, e

The student will investigate and understand that oceans are complex, interactive physical, chemical, and biological systems and are subject to long- and short-term variations. Key concepts include

- importance of environmental, geologic, and economic implications; and
- public policy issues concerning the oceans.

Essential Understandings	Essential Knowledge and Skills
· The oceans are environmentally and economically important. · Human activities and public policy have important consequences for the oceans. · The oceans' resources are finite and can be overexploited.	<u>Knowledge</u> · Algae in the oceans are an important source of atmospheric oxygen. · The oceans are an important source of food and raw materials. · Pollution and over-fishing can harm or deplete valuable resources.

Standard ES.11 c, d

The student will investigate and understand that oceans are complex, interactive physical, chemical, and biological systems and are subject to long- and short-term variations. Key concepts include

- systems interactions (energy transfer, weather, and climate); and
- features of the seafloor (continental margins, trenches, mid-ocean ridges, and abyssal plans) reflect tectonic processes.

Essential Understandings	Essential Knowledge and Skills
· The ocean is the single largest reservoir of heat at the Earth's surface. · The topography of the seafloor is at least as variable as that on the continents.	<u>Knowledge</u> · The stored heat in the ocean drives much of the Earth's weather. · The stored heat in the ocean causes climate near the ocean to be milder than climate in the interior of continents. · Features of the seafloor that are related to plate tectonic processes include mid-ocean ridges and trenches. · Other major topographic features of the oceans are continental shelves, continental slopes, abyssal plains, and seamounts.

Standard ES.12 a, b

The student will investigate and understand the origin and evolution of the atmosphere and the interrelationship of geologic processes, biologic processes, and human activities on its composition and dynamics. Key concepts include

- scientific evidence for atmospheric changes over geologic time; and
- current theories related to the effects of early life on the chemical makeup of the atmosphere.

Essential Understandings	Essential Knowledge and Skills
The composition of the Earth's atmosphere has changed over geologic time.	Knowledge · The early atmosphere contained little oxygen and more carbon dioxide than the modern atmosphere. · Early photosynthetic life (algae and blue-green algae) generated oxygen and consumed carbon dioxide. · It was only after early photosynthetic life generated oxygen that animal life became possible.

Standard ES.12 c

The student will investigate and understand the origin and evolution of the atmosphere and the interrelationship of geologic processes, biologic processes, and human activities on its composition and dynamics. Key concepts include

- comparison of the Earth's atmosphere to that of other planets.

Essential Understandings	Essential Knowledge and Skills
The Earth's atmosphere is unique in the solar system in that it contains substantial oxygen.	Knowledge · The Earth's atmosphere is 21 percent oxygen, 78 percent nitrogen, and 1 percent trace gases. · The atmosphere of Venus is mostly carbon dioxide and very dense. · The Martian atmosphere is very thin and mostly carbon dioxide.

Standard ES.12 d, e

The student will investigate and understand the origin and evolution of the atmosphere and the interrelationship of geologic processes, biologic processes, and human activities on its composition and dynamics. Key concepts include

- atmospheric regulation mechanisms; and
- potential atmospheric compositional changes due to human, biologic, and geologic activity.

Essential Understandings	Essential Knowledge and Skills
The composition of the atmosphere can change due to human, biologic, and geologic activity.	<u>Knowledge</u> · Human activities have increased the carbon dioxide content of the atmosphere. · Man-made chemicals have decreased the ozone concentration in the upper atmosphere. · Volcanic activity and meteorite impacts can inject large quantities of dust and gases into the atmosphere. · The ability of the Earth's atmosphere to absorb and retain heat is affected by the presence of gases like water vapor and carbon dioxide. <u>Skills</u> Explain how volcanic activity or meteor impacts could affect the atmosphere and life on Earth.

Standard ES.13 a, b, c

The student will investigate and understand energy transfer between the sun, Earth, and the Earth's atmosphere drives weather and climate on Earth. Key concepts include

- observation and collection of weather data;
- prediction of weather patterns; and
- weather phenomena and the factors that affect climate.

Essential Understandings	Essential Knowledge and Skills
· Weather and climate are different. · The Earth's surface is much more efficiently heated by the sun than is the atmosphere. · The amount of energy reaching any given point on the Earth's surface is controlled by the angle of sunlight striking the surface and varies with the seasons. · Winds are created by uneven heat distribution at the Earth's surface and modified by the rotation of the Earth. · Energy transfer between the Earth's surface and the atmosphere creates the weather. · Both weather and climate are measurable and, to a certain extent, predictable.	<u>Knowledge</u> · Weather describes day-to-day changes in atmospheric conditions. · Climate describes the typical weather patterns for a given location over a period of many years. · Areas near the equator receive more of the sun's energy per unit area than areas nearer the poles. · The conditions necessary for cloud formation are: air is at or below dew point; and condensation nuclei are present. · Cloud droplets can join together to form precipitation. · The four major factors affecting climate are latitude, elevation, proximity to bodies of water, and position relative to mountains**.**

Standard ES.13 a, b, c (continued)

Essential Understandings	Essential Knowledge and Skills
	· The Coriolis effect causes deflections of the atmosphere due to the rotation of the Earth. · The Coriolis effect helps to create the global wind pattern. · A tornado is a narrow, violent funnel-shaped column of spiral winds that extends downward from the cloud base to Earth. · A hurricane is a tropical cyclone (counterclockwise movement of air) characterized by sustained winds of 120 kilometers per hour or greater. Skills · Label a diagram of global wind patterns. · Read and interpret data from a thermometer, a barometer, and a psychrometer. · Read and interpret a weather map. · Identify cirrus, cumulus, and stratus clouds.

Standard ES.14 a

The student will investigate and understand the planets and other members of the solar system: the history and contributions of the space program; and the concept related to the origin and evolution of the solar system, galaxy, and universe. Key concepts include

- characteristics of the sun, planets, their moons, comets, meteors, and asteroids.

Essential Understandings	Essential Knowledge and Skills
The solar system consists of many types of celestial bodies.	Knowledge · The sun consists largely of hydrogen gas. Its energy comes from nuclear fusion of hydrogen to helium. · There are essentially two types of planets in our solar system. · The four inner (terrestrial) planets consist mostly of solid rock. · Four of the outer planets are gas giants, consisting of thick outer layers of gaseous materials, perhaps with a small rocky core. · The fifth outer planet Pluto has an unknown composition, and appears solid. · Moons are natural satellites of planets that vary widely in composition.

Standard ES.14 a (continued)

Essential Understandings	Essential Knowledge and Skills
	· Comets orbit the sun and consist mostly of frozen gases. · Asteroids are rocky or metallic iron objects ranging in size from millimeters to kilometers. They are the source of most meteorites. · Much of our knowledge about the solar system is a result of space exploration efforts. These efforts continue to improve our understanding of the solar system. · Apollo 11 was the first manned landing on the moon. <u>Skills</u> Draw a diagram of the solar system and label the planets.

Standard ES.14b

The student will investigate and understand the planets and other members of the solar system: the history and contributions of the space program; and the concepts related to the origin and evolution of the solar system, galaxy, and universe. Key concepts include

- cosmology and the origin of the stars and stellar systems (the Big Bang, the solar nebular theory, stellar evolution, star systems, nebulae, constellations, and galaxies).

Essential Understandings	Essential Knowledge and Skills
· The universe is vast and very old. · The Big Bang Theory is our best current hypothesis for the origin of the universe. · The solar nebular theory is our best current hypothesis for the origin of the solar system. · Stars have a finite lifetime and evolve over time. · The mass of a star controls its evolution, length of its lifetime, and ultimate fate.	<u>Knowledge</u> · The Big Bang Theory states that the universe began as a dense sphere that expanded and eventually condensed into galaxies. · The solar nebular theory explains that the planets formed through condensing of the solar nebula. · Stars form by condensation of interstellar gas. · Galaxies are collections of large numbers (billions) of stars. The sun is in the Milky Way galaxy. · The solar system is located in the Milky Way Galaxy. · The basic types of galaxies are spiral, elliptical, and irregular.

Standard ES.14 b (continued)

Essential Understandings	Essential Knowledge and Skills
	· A light-year is the distance light travels in one year and is the most commonly used measurement for distance in astronomy. · Much of our information about our galaxy and the universe comes from ground-based observations. · The Hubble Space telescope has greatly improved our understanding of the universe.

Science Standards of Learning

Teacher Resource Guide

Biology

Commonwealth of Virginia
Department of Education
Richmond, Virginia
2000

Standard BIO.1 a, b, c, i, j

The student will plan and conduct investigations in which

- observations of living things are recorded in the lab and in the field;
- hypotheses are formulated based on observations;
- variables are defined and investigations are designed to test hypotheses;
- appropriate technology is used for gathering and analyzing data and communicating results; and
- research is based on popular and scientific literature.

Essential Understandings	Essential Knowledge and Skills
· Active participation in scientific investigations is necessary to develop an understanding of biology as an experimental science. · The continual use and development of cognitive and manipulative skills associated with the formulation of the scientific explanations is important. · The design of sound scientific experiments relies on systematic preliminary observations and data, collected in the laboratory and in the field, as well as on a knowledge base gained from an examination of related research. Prior establishment of an adequate knowledge base is essential before hypotheses can be developed and tested.	<u>Skills</u> · Collect preliminary observations, both qualitative and quantitative. · Make clear distinctions among observations, inferences and predictions. · Critically examine and discuss the validity of results reported in scientific and popular literature and databases. · Formulate hypotheses based on cause and effect relationships. · Justify the hypotheses based on both on preliminary observations and on popular and/or scientific literature.

Standard BIO.1 a, b, c, i, j (continued)

Essential Understandings	Essential Knowledge and Skills
	· Identify the independent variable (IV), and the values of the IV that will be used in the experiment. · Select dependent variables that allow collection of quantitative data. · Use appropriate technology for data collection, including: probeware interfaced to a graphing calculator and/or computer, microscope, video microscope, or digital camera with image processing software. · Identify variables that must be held constant. · Establish controls as appropriate. · Write clear, replicable procedures. · Record quantitative data in clearly labeled tables with units. · Include labeled diagrams in the data record.

Standard BIO.1 d, e, f, g, h

The student will plan and conduct investigations in which

- graphing and arithmetic calculations are used as tools in data analysis;
- conclusions are formed based on recorded quantitative and qualitative data;
- impacts of sources of error inherent in experimental design are identified and discussed;
- validity of data is determined; and
- alternative explanations and models are recognized and analyzed.

Essential Understandings	Essential Knowledge and Skills
· The analysis of evidence and data is essential in order to make sense of the content of science. · Multiple data manipulation and analysis strategies are available to help explain results of quantitative investigations. · Data and evidence should be from a variety of sources including student investigation, peer investigation, and databases.	<u>Skills</u> · Determine the range, mean, and values for data, using a graphing calculator and/or computer spreadsheet software. · Plot data graphically, showing independent and dependent variables. · Describe linear mathematical functions from the data, where appropriate, using a graphing calculator and/or computer spreadsheet. · Discuss accuracy, confidence, and sources of experimental error based on number of trials and variance in the data. · Recognize and discuss contradictory or unusual data.

Standard BIO.1 d, e, f, g, h (continued)

Essential Understandings	Essential Knowledge and Skills
	· Use evidence, apply logic, and construct an argument for conclusions based on reported data. · Determine the extent to which data supports/does not support the hypothesis, and propose further hypotheses and directions for continued research. · Communicate results of experimentation, using presentation software as appropriate.

Standard BIO.2 a, b, c, d

The student will investigate and understand the history of biological concepts. Key concepts include

- evidence supporting the cell theory;
- scientific explanations of the development of organisms through time;
- causative agents of disease; and
- the evolution of the DNA model.

Essential Understandings	Essential Knowledge and Skills
In order to develop an understanding of biology as an experimental science, there must be a knowledge of how scientific discoveries are made and how these discoveries have led to the accumulation of knowledge that is presented in textbooks. A historical perspective encourages the examination of concrete examples in the context from which they were developed.	Knowledge · The development and refinement of magnifying lenses and light microscopes made the observation and description of microscopic organisms and living cells possible. · The ability to see microscopically led to the development of the cell theory. · Continued advances in microscopy allowed observation of cell organelles and ultrastructure. Current technology allows the observation of cellular processes underlying both cell structure and function. · Scientists have developed hypotheses about conditions on early Earth that could have led to the formation of the first organic molecules, early self-replicating molecules, the source of free oxygen in Earth's atmosphere, and appearance of prokaryotic and later eukaryotic cells.

Standard BIO.2 a, b, c, d (continued)

Essential Understandings	Essential Knowledge and Skills
	· The scientific problem that led to the theory of natural selection was how to explain similarities within the great diversity of existing and fossil organisms. Although most scientists now accept the theory of natural selection, some differences exist concerning the details of the process and how rapidly populations of organisms change over time. · Throughout history people have created explanations for disease. The introduction of the germ theory led to the understanding that many diseases are caused by microorganisms. · Changes in health practices have resulted from the acceptance of the germ theory of disease. · The modern approach emphasizes sanitation, the safe handling of food and water, aseptic techniques to keep germs out of the body, and the development of vaccinations and other chemicals and processes to destroy microorganisms. · Once DNA was shown to be the genetic material, a race among scientists took place to work out its structure.

Standard BIO.2 a, b, c, d (continued)

Essential Understandings	Essential Knowledge and Skills
	· Studies of the amounts of each DNA base in different organisms led to the concept of complementary base-pairing. · Interpretations of x-ray photographs of DNA were used to describe the shape and dimensions of the molecule. An analysis of this and other available data led to a structural model for the DNA double helix. · The double helix model explained how hereditary information is passed on and provided the basis for an explosion of scientific research in molecular genetics.

Standard BIO.2 e

The student will investigate and understand the history of biological concepts. Key concepts include

· the collaborative efforts of scientists, past and present.

Essential Understandings	Essential Knowledge and Skills
· The scientific establishment sometimes rejects new ideas, and that new discoveries often spring from unexpected findings. · Scientific knowledge usually grows slowly, through contributions from many different investigators from diverse cultures.	<u>Knowledge</u> Science depends on experimental and observational confirmation and is subject to change as new evidence becomes available.

Standard BIO.3 a

The student will investigate and understand biochemical principles essential for life. Key concepts include

· water chemistry and its impact on life processes.

Essential Understandings	Essential Knowledge and Skills
· Water is essential for life on Earth. · About two thirds of the mass of a cell is made up of water, and most of the biochemical processes of life occur in water solutions.	<u>Knowledge</u> · Water is able to absorb large amounts of heat, so lakes and oceans stabilize air and land temperatures. · Water absorbs heat when it evaporates, allowing organisms to get rid of excess heat. · In the solid form, ice floats, preventing lakes and oceans from freezing solid. · Water is able to dissolve many substances so the water inside and outside of cells can carry nutrients into and around cells, and wastes away from cells. · Diffusion occurs in cells when substances (oxygen, carbon dioxide, salts, sugars, amino acids) which are dissolved in water move from an area of higher concentration to an area of lower concentration.

Standard BIO.3 a (continued)

Essential Understandings	Essential Knowledge and Skills
	· Osmosis refers to the movement of water molecules through a semi-permeable membrane from an area of greater water concentration or pressure to an area of lesser water concentration or pressure. · The pH scale goes from 0 to 14. The pH of pure water is 7. Substances added to water can lower or raise the pH. A solution with a pH below 7 is acidic. A solution with a pH above 7 is basic. · Organisms can only tolerate small changes in pH because every cell has a particular pH at which it functions best. For example, changes in pH cause changes in enzyme conformation, resulting in a change in activity.

Standard BIO.3 b, c

The student will investigate and understand biochemical principles essential for life. Key concepts include

- the structure and function of macromolecules; and
- the nature of enzymes.

Essential Understandings	Essential Knowledge and Skills
· Most life processes are series of chemical reactions influenced by environmental and genetic factors. · Inside every cell is a concentrated mixture of thousands of different macromolecules which form a variety of specialized structures that carry out cell functions such as energy production, transport, waste disposal, synthesis of new molecules, and storage of genetic material. · Protein molecules that are assembled in cells carry out most of the cells' work. The function of each protein molecule depends on its specific conformation. The chemical reactions that occur inside cells are directly controlled by a large set of protein molecules called enzymes, whose functions depend on their specific shapes.	<u>Knowledge</u> · The main components of a living cell are carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur. · Carbon atoms can easily bond to several other carbon atoms in chains and rings to form large complex molecules. · Cells can make a variety of macromolecules from a relatively small set of monomers. · The primary functions of carbohydrate and lipid macromolecules are: carbohydrates provide and store energy; lipids insulate, store energy, and make up cell membranes. · Nucleic acids (DNA and RNA) control cell activities by directing protein synthesis.

Standard BIO.3 b, c (continued)

Essential Understandings	Essential Knowledge and Skills
	· Some proteins are structural (hair, nails). Others function in transport (hemoglobin), movement (muscle fibers and cytoskeletal elements), defense (antibodies), and regulation of cell functions (hormones and enzymes). · Proteins are polymers made by linking together amino acid monomers. · A protein's structure depends on its specific conformation. The sequence of amino acids and the shape of the chain are a consequence of attractions between the chain's parts. · Each enzyme has a definite three-dimensional shape that allows it to recognize and bind with its substrate. In living cells, enzymes control the rate of metabolic reaction by acting as catalysts. · Most cells function best within a narrow range of temperature and pH. At very low temperatures, reaction rates are too slow. High temperatures or extremes of pH can irreversibly change the structure of proteins and alter their function.

Standard BIO.3 d

The student will investigate and understand biochemical principles essential for life. Key concepts include

· the significance of the relationship between photosynthesis and respiration.

Essential Understandings	Essential Knowledge and Skills
· Plant cells and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy-rich organic compounds and release oxygen into the environment. · The process of photosynthesis provides a vital connection between the sun and the energy needs of living systems. · The breakdown of nutrient molecules enables all cells to store energy in specific chemicals that are used to carry out the life functions of the cell.	<u>Knowledge</u> · Photosynthesis and cell respiration are complementary processes for cycling carbon dioxide and oxygen in ecosystems. · During photosynthesis, cells trap energy from sunlight with chlorophyll, and use the energy, carbon dioxide and water to produce energy-rich organic molecules and oxygen. · During cell respiration, eukaryotic cells burn organic molecules with oxygen to produce energy, carbon dioxide, and water. · Photosynthesis and cell respiration are complementary processes for energy transfer in ecosystems. · Light is the initial source of energy for most communities.

Standard BIO.3 d (continued)

Essential Understandings	Essential Knowledge and Skills
	· Photosynthesis involves an energy conversion in which light energy is converted to chemical energy in specialized cells (examples: plants and some protists). · Cells release the chemical energy stored in the products of photosynthesis. This energy is transported within the cell in the form of ATP. · When cells need energy to do work, certain enzymes release the energy stored in the chemical bonds in ATP.

Standard BIO.4 a, b

The student will investigate and understand relationships between cell structure and function. Key concepts include

- characterizing prokaryotic organisms; and
- exploring the diversity and variation of eukaryotes.

Essential Understandings	Essential Knowledge and Skills
· The cell theory is the unifying theme in biology because it emphasizes the similarity of all living things. · The simplest life forms exhibiting cellular structure are the prokaryotes. · Cell structure is one of the ways in which organisms differ from each other. · The diversity which exists ranges from simple prokaryotic cells to complex multi-cellular organisms.	<u>Knowledge</u> · The cell theory states that all living things are composed of cells and cells come from other cells by cell reproduction. · Earth's first cells were prokaryotes. · Prokaryotic cells exist in two major forms: Eubacteria and Archaebacteria. · Prokaryotes are the Earth's most abundant inhabitants. They can survive in a wide range of environments and obtain energy in a variety of ways. · Eukaryotes arose from prokaryotes and developed into larger more complex organisms from single-celled Protista to multi-cellular fungi, plants and animals.

Standard BIO.4 a, b (continued)

Essential Understandings	Essential Knowledge and Skills
	· Several differences between eukaryotes and prokaryotes include size, genetic material surrounded by a nuclear membrane, and the addition of mitochondria and chloroplasts. · Cellular differences between plant and animal cells include the presence of a cell wall that gives the plant cell a defined shape, chloroplast, and number of vacuoles.

Standard BIO.4 c, d

The student will investigate and understand relationships between cell structure and function. Key concepts include

- building analogies between the activities of a single cell and a whole organism; and
- modeling the cell membrane, cell communication, and cell recognition.

Essential Understandings	Essential Knowledge and Skills
· Cells are the basic units of structure and function of all living things. · Relationships between structure and function can be examined at each of the hierarchical levels of organizations: molecular, cellular, organism, population, community, and ecosystem. · Cells contain specialized structures to perform functions necessary for life. · Cellular activities necessary for life include chemical reactions that facilitate acquiring energy, reproduction, and adaptation/maintaining homeostasis. · Homeostasis of a cell is maintained by a plasma membrane comprised of a variety of organic molecules which controls the movement of material	<u>Knowledge</u> · Essential cell structures and their function include - the nucleus (contains DNA, site where RNA is made) - ribosomes (site of protein synthesis) - mitochondria (site of cell respiration) - chloroplast (site of photosynthesis) - endoplasmic reticulum (transports materials through the cell) - Golgi (cell products are packaged for export) - lysosomes (contain digestive enzymes) - cell membrane (controls what enters and leaves the cell) - cell wall (provides support). · Some organisms exist as a single cell while others are composed of many cells, each specialized to perform distinct metabolic functions.

Standard BIO.4 c, d (continued)

Essential Understandings	Essential Knowledge and Skills
in and out of the cell, communication between cells, and the recognition of cells to facilitate multiple metabolic functions.	· The basic processes necessary for living things to survive are the same for a single cell as they are for a more complex organism. · A single-celled organism has to conduct all life processes by itself. A multicellular organism has groups of cells that specialize to perform specific functions. · Cell specialization occurs during the development of a multicellular organism. The genetic information necessary for all cellular functions remains in each cell but may not be used. · The fluid mosaic model of a membrane emphasizes the arrangement and function of a bilayer of phospholipids, transport proteins, and cholesterol. · The important functions of the membrane include: diffusion, osmosis, passive and active transport, recognition of foreign antigens, recognition of self surface proteins, and receptor sites for chemical signals.

Standard BIO.5 a, b, c, g

The student will investigate and understand life functions of monerans, protists, fungi, plants, and animals including humans. Key concepts include

- how their structures are alike and different;
- comparison of their metabolic activities;
- analyses of their responses to the environment; and
- observation of local organisms when applicable.

Essential Understandings	Essential Knowledge and Skills
· The millions of different organisms that live on Earth today share many structural and metabolic features, including cellular organization, common molecular mechanisms for energy transformation and utilization and maintenance of homeostasis, common genetic code, and mechanisms for the transmission of traits from one generation to the next. · The diversity that is evident in the natural world can be studied in the local environment in the context of variations on a common theme.	<u>Skills</u> Differentiate and give examples from local ecosystems: · autotrophs and heterotrophs (producers, consumers, and decomposers) · multicellular and unicellular organisms · motile and non-motile organisms · organisms with and without cell walls · sexually and asexually reproducing organisms · aquatic and terrestrial organisms · behavioral responses to the environment.

Standard BIO.5 d, e

The student will investigate and understand life functions of monerans, protists, fungi, plants, and animals including humans. Key concepts include

- maintenance of homeostasis; and
- human health issues, human anatomy, body systems and life functions.

Essential Understandings	Essential Knowledge and Skills
· Like other organisms, human beings are composed of groups of cells (tissues, organs, and organ systems) that are specialized to provide the human organism with the basic requirements for life: obtaining food and deriving energy from it, maintaining homeostasis, coordinating body functions, and reproducing. · Understanding normal body functioning assists in understanding situations, both hereditary and environmental, in which functioning is impaired.	<u>Knowledge</u> · For the body to use food for energy, the food must first be digested into molecules that are absorbed and transported to cells, where the food is used for energy, and for repair and growth. · To burn food for the release of energy, oxygen must be supplied to cells and carbon dioxide removed. The respiratory system responds to changing demands by increasing or decreasing breathing rate in order to maintain homeostasis. · The circulatory system, which moves all of these substances to or from cells, responds to changing demands by increasing or decreasing heart rate and blood flow in order to maintain homeostasis. · The urinary system disposes of dissolved waste molecules, the intestinal tract removes solid wastes, and the skin and lungs rid the body of heat energy.

Standard BIO.5 d, e (continued)

Essential Understandings	Essential Knowledge and Skills
	· Specialized cells of the immune system and the molecules they produce are designed to protect against organisms and substances that enter from outside the body, and against some cancer cells that arise from within. · Communication between cells is required for coordination of body functions. The nerves communicate with electrochemical signals, hormones circulate through the blood, and some cells secrete substances that spread only to nearby cells. · Environmental factors that impact human health include: diet, exercise, sleep, stress, toxic substances that enter the body, viruses, and other living organisms that infect the body. · Genetic predispositions towards diseases impact human health. Awareness of one's genetic make-up allows individuals to make lifestyle changes that can enhance their quality of life.

Standard BIO.5 f

The student will investigate and understand life functions of monerans, protists, fungi, plants, and animals including humans. Key concepts include

· how viruses compare with organisms.

Essential Understandings	Essential Knowledge and Skills

Viruses do not share many of the characteristics of living organisms.	<u>Knowledge</u>
	· Viruses are not cells. Basic viral structure consists of a nucleic acid core surrounded by a protein coat.
	· Viruses can only reproduce inside another living cell, the host cell.
	· The viral reproductive process is called the lytic cycle. It includes the following steps:
	  · A virus attaches to a host cell's membrane and injects its nucleic acid into the host cell.
	  · The viral nucleic acid takes over protein synthesis, creating new viruses.
	  · The host cell bursts, lyses, releasing the newly formed viruses.

Standard BIO.6 a, b, c

The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include

- cell division;
- sex cell formation; and
- cell specialization.

Essential Understandings	Essential Knowledge and Skills
· All living cells come from other living cells. During mitosis the nucleus of the cell divides, forming two nuclei with identical genetic information. · Many organisms are capable of combining genetic information from two parents to produce offspring. Sex cells are produced through meiosis. This allows sexually reproducing organisms to produce genetically differing offspring. · The many body cells of an individual organism can be specialized to perform different functions, even though they are all descended from a single cell and contain essentially the same genetic information.	<u>Knowledge</u> · Mitosis produces two genetically identical cells. · Meiosis occurs in sexual reproduction when a diploid germ cell produces four haploid daughter cells that can mature to become gametes (sperm or egg). · Mitosis and meiosis refer to division of the nuclear material. Cytokinesis is the division of the cytoplasm and organelles. · A typical cell goes through a process of growth, development, and reproduction called the cell cycle.

Standard BIO.6 d

The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include

· prediction of inheritance of traits on the laws of heredity.

Essential Understandings	Essential Knowledge and Skills
Geneticists apply mathematical principles of probability to Mendel's laws of inheritance in order to predict the results of simple genetic crosses.	<u>Knowledge</u> · Mendel's laws of heredity are based on his mathematical analysis of observations of patterns of inheritance of traits. · Simple genetic recombinations are governed by the laws of probability. · Genotype describes the genetic make-up of an organism and phenotype describes the organism's appearance based on its genes. · Homozygous individuals have two identical alleles for a particular trait, while heterozygous individuals have contrasting alleles. · When one allele masks the effect of another, that allele is called dominant, and the other recessive.

Standard BIO.6 d (continued)

Essential Understandings	Essential Knowledge and Skills
	Skills · Predict possible gametes in a dihybrid cross, given parental genotypes. · Use a Punnett square to show all possible combinations of gametes and the likelihood that particular combinations will occur in monohybrid crosses.

Standard BIO.6 e

The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include

- effects of genetic recombination and mutation.

Essential Understandings	Essential Knowledge and Skills
· Genetically diverse populations are more likely to survive changing environments. · Recombination and mutation provide for genetic diversity. · Some new gene combinations have little effect; some can produce organisms that are better suited to their environments; others can be deleterious.	<u>Knowledge</u> · The sorting and recombination of genes in sexual reproduction results in a great variety of gene combinations in the offspring of any two parents. · Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every cell that develops from it, causing an altered phenotype. · An altered phenotype may be beneficial or detrimental. · Sometimes entire chromosomes can be added or deleted, resulting in a genetic disorder such as Trisomy 21 (Downs syndrome).

Standard BIO.6 f

The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include

· events involved in the construction of proteins.

Essential Understandings	Essential Knowledge and Skills
· DNA stores the information for directing the construction of proteins within a cell. These proteins determine the phenotype of an organism. · The genetic information encoded in DNA molecules provides instructions for assembling protein molecules. The code is virtually the same for all life forms. · Before a cell divides, the instructions are duplicated so that each of the two new cells gets all the necessary information for carrying on life functions.	<u>Knowledge</u> · The genetic code is a sequence of DNA nucleotides in the nucleus of eukaryotic cells. · DNA is a polymer of four nucleotide monomers. A DNA nucleotide is identified by the base it contains: adenine (A), guanine (G), and cytosine (C) or thymine (T). · DNA is a double-stranded molecule. The strands are connected by complementary nucleotide pairs (A-T and C-G) like rungs on a ladder. The ladder twists to form a double helix. · The genetic code is the sequence of DNA nucleotides. · In order for cells to make proteins, the DNA code must be transcribed (copied) to messenger RNA (mRNA). · The mRNA carries the code from the nucleus to the ribosomes in the cytoplasm.

Standard BIO.6 f (continued)

Essential Understandings	Essential Knowledge and Skills
	· RNA is a single-stranded polymer of four nucleotide monomers. A RNA nucleotide is identified by the base it contains: adenine (A), guanine (G), and cytosine (C) or uracil (U). · At the ribosome, amino acids are linked together to form specific proteins. The amino acid sequence is directed by the mRNA molecule. · Cells pass on their genetic code by replicating (copying) their DNA. · During DNA replication, enzymes unwind and unzip the double helix and each strand serves as a template for building a new DNA molecule. Free nucleotides bond to the template (A-T and C-G) forming a complementary strand. The final product of replication is two identical DNA molecules. <u>Skills</u> Given a DNA sequence, write a complementary mRNA strand (A-U, T-A, C-G and G-C).

Standard BIO.6 g

The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include

· exploration of the impact of DNA technologies.

Essential Understandings	Essential Knowledge and Skills
· DNA technologies allow scientists to identify, study, and modify genes. · Genetic engineering techniques are used in a variety of industries, in agriculture, in basic research, and in medicine.	<u>Knowledge</u> · Forensic identification is an example of the application of DNA technology. · There is great potential for the development of useful products through genetic engineering (e.g., human growth hormone, insulin, and resistant fruits and vegetables). · The Human Genome Project is a collaborative effort to map the entire gene sequence of organisms. This information will be useful in detection, prevention, and treatment of many genetic diseases. · The potential for identifying and altering genomes raises practical and ethical questions. · Cloning is the production of genetically identical cells and/or organisms.

Standard BIO.7 a, g

The student will investigate and understand the basis for modern classification systems. Key concepts include

- structural similarities in organisms; and
- examination of local flora and fauna where applicable.

Essential Understandings	Essential Knowledge and Skills
· Biological classifications are based on how organisms are related. · Organisms are classified into a hierarchy of groups and subgroups based on similarities that reflect their relationships over a period of time. · Species is the basic unit of classification. · Investigations of local flora and fauna provide opportunities to enhance understanding and stimulate interest in local environmental issues by developing and applying classification systems in the field.	<u>Knowledge</u> · Binomial nomenclature is a standard way of identifying a species with a scientific two-word name. The first word is the genus name and the second the species name. · A species is defined as a group of organisms that has the ability to interbreed and produce fertile offspring. <u>Skills</u> · Construct and utilize dichotomous keys to classify groups of objects and organisms. · Describe relationships based on homologous structures. · Observe and identify flora and fauna in a local community, using field guides and dichotomous keys for identifying and describing organisms that characterize the local biome.

Standard BIO.7 b

The student will investigate and understand the basis for modern classification systems. Key concepts include · fossil record interpretation.	
Essential Understandings	**Essential Knowledge and Skills**
Information about relationships among present organisms and those that inhabited Earth in the past is gained by comparing developmental stages of organisms and by examining and interpreting the fossil record.	Skills Compare structural characteristics of an extinct organism, as evidenced by its fossil record, with present, familiar organisms.

Standard BIO.7 c, f

The student will investigate and understand the basis for modern classification systems. Key concepts include

- comparison of developmental stages in different organisms; and
- systems of classification that are adaptable to new scientific discoveries.

Essential Understandings	Essential Knowledge and Skills
Information about relationships among present organisms and those that inhabited Earth in the past is gained by comparing developmental stages of organisms and by examining and interpreting the fossil record. This information is continually being gathered and used to modify and clarify existing classification systems.	Skills · Recognize similarities in embryonic stages in diverse organisms in the animal kingdom, from zygote through embryo. · Interpret a cladogram or phylogentic tree showing evolutionary relationships among organisms.

Standard BIO.7 d

The student will investigate and understand the basis for modern classification systems. Key concepts include

· examination of protein similarities and differences among organisms.

Essential Understandings	Essential Knowledge and Skills
Similarities among organisms on the structural and metabolic levels are reflected in the large degree of similarity in proteins and nucleic acids of different organisms. Diversity is the product of variations in these molecules.	Skills Describe relationships between organisms, given amino acid or nucleotide sequences.

Standard BIO.8 a

The student will investigate and understand how populations change through time. Key concepts include

· examining evidence found in fossil records.

Essential Understandings	Essential Knowledge and Skills
Although there is not a complete record of ancient life for the past 3.5 billion years, a great deal of modern knowledge about the history of life comes from the fossil record.	Knowledge · A fossil is any evidence of an organism that lived long ago. · Scientists have used the fossil record to construct a history of life on Earth. Skills Determine the relative age of a fossil given information about its position in the rock, and absolute dating by radioactive decay.

Standard BIO.8 b, c, d

The student will investigate and understand how populations change through time. Key concepts include

- investigating how variation of traits, reproductive strategies, and environmental pressures impact on the survival of the populations;
- recognizing how adaptations lead to natural selection; and
- exploring how new species emerge.

Essential Understandings	Essential Knowledge and Skills
· Genetic mutations and variety produced by sexual reproduction allow for diversity within a given population. · Many factors can cause a change in the frequency of a gene over time. · Depending on the rate of adaptation, the rate of reproduction of an organism, and the environmental factors present, structural adaptations may take millions of years to develop.	<u>Knowledge</u> · Populations are groups of interbreeding individuals that live in the same place at the same time, and compete with each other for food, water, shelter, and mates. · Populations produce more offspring than the environment can support. · Organisms with certain genetic variations will be favored to survive and pass their variations on to the next generation. · The unequal ability of individuals to survive and reproduce leads to the gradual change in a population, generation after generation. · Through his observations made in the Galapagos Islands, Charles Darwin formulated a theory of how species change over time called natural selection.

Standard BIO.8 b, c, d (continued)

Essential Understandings	Essential Knowledge and Skills
	· Natural selection is governed by the principles of genetics. The change frequency of a gene in a given population leads to a change in a population and may result in the emergence of a new species. · Natural selection operates on populations over many generations. · Mutations are important in how populations change over time because they result in genetic changes to the gene pool. · Adaptations sometimes arise in response to environmental pressures, for example: the development of antibiotic resistance in bacterial populations, morphological changes in the peppered moth population, pesticide resistance.

Standard BIO.9 a

The student will investigate and understand dynamic equilibria within populations, communities, and ecosystems. Key concepts include

· interactions within and among populations including carrying capacities, limiting factors, and growth curves.

Essential Understandings	Essential Knowledge and Skills
As any population of organisms grows, it is held in check by interactions among a variety of biotic and abiotic factors.	<u>Knowledge</u> · A community is a collection of interacting populations. · Population growth curves exhibit many characteristics such as: initial growth stage, exponential growth, steady state, decline, and extinction. · Limiting factors are the components of the environment that restrict the growth of populations. · Carrying capacity is the number of organisms that can be supported by the resources in an ecosystem. · Abiotic factors are the nonliving elements in an ecosystem such as temperature, moisture, air, salinity, and pH. Biotic factors are all the living organisms that inhabit the environment including predators, food sources, and competitors.

Standard BIO.9 a (continued)

Essential Understandings	Essential Knowledge and Skills
	· Symbiosis is a close and permanent relationship between organisms of two different species. Examples include mutualism, commensalism, and parasitism. Skills Graph and interpret a population growth curve.

Standard BIO.9 b, c

The student will investigate and understand dynamic equilibria within populations, communities, and ecosystems. Key concepts include

· nutrient cycling and energy flow through ecosystems; and
· succession patterns in ecosystems.

Essential Understandings	Essential Knowledge and Skills
· Ecosystems demonstrate an exchange of energy and nutrients among inhabiting organisms. · The gradual change in an ecosystem that occurs as communities slowly replace one another is known as ecological succession.	<u>Knowledge</u> · An ecosystem consists of all the interacting species and the abiotic environment in a given geographic area. · Nutrients cycle through an ecosystem. The most common examples include carbon, oxygen, nitrogen, and water. · Flow of energy occurs between trophic levels in all ecosystems and can be depicted as follows: - food chain - food web - pyramid of energy - pyramid of biomass - pyramid of numbers. · Ecological succession is a series of changes in a community in which new populations of organisms gradually replace existing ones.

Standard BIO.9 b, c (continued)

Essential Understandings	Essential Knowledge and Skills
	· A climax community occurs when succession slows down and a stable community is established. The climax community is made up of organisms that are successful at competing for resources in a given environment. The climax community in most of Virginia is a deciduous oak-hickory (hardwood) forest. Skills Given an illustration of a food chain and a food web, describe each organism as a producer, consumer, or decomposer.

Standard BIO.9 d, e

The student will investigate and understand dynamic equilibria within populations, communities, and ecosystems. Key concepts include

- the effects of natural events and human influences on ecosystems; and
- analysis of local ecosystems.

Essential Understandings	Essential Knowledge and Skills
· As the human population increases so does human impact on the environment. · Investigations of local ecosystems provide opportunities for students to enhance their understanding and stimulate interest in local environmental issues by applying ecological principles in the field.	<u>Knowledge</u> · Human activities such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming have changed the Earth's land, oceans, and atmosphere. · Some of these changes have decreased the capacity of the environment to support some life forms. <u>Skills</u> · In a local area near the school and/or in a larger geographical area such as the Chesapeake Bay watershed, identify and describe an ecosystem, including - effects of biotic and abiotic components - examples of interdependence

	- evidence of human influences - energy flow and nutrient cycling - diversity analysis - ecological succession.

Science Standards of Learning

Teacher Resource Guide

Chemistry

Commonwealth of Virginia
Department of Education
Richmond, Virginia
2000

Standard CH.1 a, b, c

The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated, produce observations and verifiable data. Key concepts include

- designated laboratory techniques;
- safe use of chemicals and equipment; and
- proper response to emergency situations.

Essential Understandings	Essential Knowledge and Skills
· Measurements of quantity include length, volume, mass, temperature, time, and pressure to the correct number of significant digits. · Techniques for experimentation involve the identification and the proper use of chemicals, the description of equipment, and the recommended statewide framework for high school laboratory safety. · Measurements are useful in gathering data about chemicals and how they behave.	**Skills** · Make the following measurements using the specified equipment: · Volume: graduated cylinder, pipette, volumetric flask, buret · Mass: electronic or dial-a-gram · Temperature: thermometer and/or temperature probe · Pressure: barometer and/or pressure probe. · Identify, locate, and know how to use laboratory safety equipment including aprons, goggles, gloves, fire extinguishers, fire blanket, safety shower, eye wash, broken glass container, and fume hood. · Demonstrate the following basic lab techniques: filtering, decanting, using chromatography, lighting gas burners.

Standard CH.1 a, b, c (continued)

Essential Understandings	Essential Knowledge and Skills

	· Identify the following basic lab equipment: beaker, flask, graduated cylinder, test tube, test tube rack, test tube holder, ring stand, wire gauze, clay triangle, crucible with lid, evaporation dish, watch glass, wash bottle, and dropping pipette.
	· Understand and demonstrate:
	  · Material Safety Data Sheet (MSDS) warnings, including handling chemicals, lethal dose (LD), hazards, disposal, chemical spill clean-up
	  · safety rules for a science
	  · laboratory safety cautions
	  · safe techniques and procedures.

Standard CH.1 d, e

The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated, produce observations and verifiable data. Key concepts include

- multiple variables are manipulated with repeated trials; and
- accurate recording, organizing, and analysis of data through repeated trials.

Essential Understandings	Essential Knowledge and Skills
· Repeated trials during experimentation ensure verifiable data. · Data tables are used to record and organize measurements.	**Skills** · Identify variables. · Predict outcome(s) when a variable is changed. · Design and perform experiments to test predictions. · Demonstrate precision (reproducibility) in measurement. · Understand accuracy in terms of closeness to the true value of a measure.

Standard CH.1 f, g

The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated, produce observations and verifiable data. Key concepts include

- mathematical and procedural error analysis; and
- mathematical manipulations (SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, dimensional analysis, use of scientific calculator).

Essential Understandings	Essential Knowledge and Skills

· Measurements must be expressed in SI units.
· Scientific notation is used to write very small and very large numbers.
· Algebraic equations represent relationships between dependent and independent variables.
· Graphed data give a picture of a relationship.
· Ratios and proportions are used in calculations.
· Significant digits of a measurement are the number of known digits together with one estimated digit.
· The last digit of any valid measurement must be estimated and is therefore uncertain.
	Skills
	· Discover and eliminate procedural errors.
	· Know most frequently used SI prefixes and their values (milli-, centi-, deci-, kilo-).
	· Demonstrate the use of scientific notation, using the correct number of significant digits with powers of ten notation for the decimal place.
	· Correctly utilize the following when graphing data:
	  · dependent variable (vertical axis)
	  · independent variable (horizontal axis)
	  · scale and units of a graph
	  · regression line (best fit curve).
	· Calculate mole ratios, percent composition, conversions, dimensional analysis, and relative atomic mass.

Standard CH.1 f, g (continued)

Essential Understandings	Essential Knowledge and Skills
· Dimensional analysis is a way of translating a measurement from one unit to another unit. · Scientific calculators can be used to manage the mathematics of chemistry. · Mathematical procedures are used to validate data.	· Use the rules for performing operations with significant digits. · Correctly use scientific calculators. · Use temperature and/or pH probes to gather data. · Read a measurement from a graduated scale stating measured digits plus the estimated digit. · Use data collected to calculate percent error. · Determine the mean of a set of measurements.

Standard CH.2 a, b, c

The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

- mass/atomic number;
- isotopes/half-lives/nuclear particles; and
- particle/mass charge.

Essential Understandings	Essential Knowledge and Skills
· The periodic table is arranged by increasing atomic numbers. · The atomic number of an element is the same as the number of protons. · In a neutral atom, the number of electrons is the same as the number of protons. · All atoms of the same element have the same number of protons. · The atomic mass for each element is the weighted average of that element's naturally occurring isotopes.	**Knowledge** · Electrons have little mass and a negative ("-") charge. They are located in electron clouds or probability clouds outside the nucleus. · Protons have a positive ("+") charge. Neutrons have no charge. Protons and neutrons are located in the nucleus of the atom and comprise most it's mass. · An isotope is an atom that has the same number of protons as another atom, but has a different number of neutrons. Some isotopes are radioactive; many are not. · Half-life is the length of time required for half of a given sample of a radioactive isotope to decay. **Skills** Determine, using a periodic chart, the atomic number, atomic mass, the number of protons, the number of electrons, and the number of neutrons of any neutral atom

	of a particular element.

Standard CH.2 d, e, f

The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

- families/groups;
- series/periods; and
- trends/patterns: atomic/nuclear radii, electronegativity, shielding effect.

Essential Understandings	Essential Knowledge and Skills
· Periodicity is regularly repeating patterns or trends in the chemical and physical properties of the elements arranged in the periodic table. · Vertical columns called groups have similar properties because of their similar valence electron configurations. · Horizontal rows called periods have predictable properties based on an increasing number of electrons in the outer orbitals.	**Knowledge** · The Periodic Law states that when elements are arranged in order of increasing atomic number, their physical and chemical properties show a periodic pattern. · The names of groups and periods on the periodic chart are alkali metals, alkaline earth metals, transition metals, halogens, inert gases, and metalloids. · Periods and groups are named by numbering columns and rows. · Some elements (oxygen, hydrogen, and nitrogen) naturally occur as diatomic molecules. · Electronegativity increases from left to right, and decreases from top to bottom.

Standard CH.2 d, e, f (continued)

Essential Understandings	Essential Knowledge and Skills
	· Shielding effect is constant across the period and increases within given groups from top to bottom. · Atomic radius decreases from left to right and increases from top to bottom within given groups. · Ionization energies generally increase from left to right and decrease from top to bottom of a given group. **Skills** Determine the Electron Configuration for elements up to Z=17.

Standard CH.2 g

The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

· electron configurations/oxidation numbers.

Essential Understandings	Essential Knowledge and Skills
· Electron configuration is the arrangement of electrons around the nucleus of an atom based on their energy level. · Atoms can gain or lose electrons within the outer energy level.	**Knowledge** · Electrons are added one at a time to the lowest energy level (Aufbau Principle). · An orbital can hold a maximum of two electrons (Pauli Exclusion Principle). · Electrons occupy equal-energy orbitals so that a maximum number of unpaired electrons results. (Hund's Rule). · Energy levels are designated 1 – 7. Orbitals are designated s, p, d, and f according to their shapes. (s, p, d, f orbitals relate to the regions of the Periodic Table.) · Loss of electrons from neutral atoms results in the formation of an ion with a positive charge (cation). · Gain of electrons by a neutral atom results in the

	formation of an ion with a negative charge (anion). · Transition metals can have multiple oxidation states.

Standard CH.2 h

The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

· chemical/physical properties.

Essential Understandings	Essential Knowledge and Skills
· Matter is classified by its chemical and physical properties. · Physical properties refer to the condition or quality of a substance that can be observed or measured without changing the substance's composition. · Chemical properties refer to the ability of a substance to undergo chemical reaction and to form a new substance.	**Knowledge** · Matter occurs as element (pure), compounds (pure), and mixtures which may be homogeneous (solutions) or heterogeneous. · Important physical properties are density, conductivity, melting point, boiling point, malleability, and ductility. · Reactivity is the tendency of an element to enter into a chemical reaction.

Standard CH.2 i

The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

· historical/quantum models.

Essential Understandings	Essential Knowledge and Skills
· Discoveries and insights related to its structure have changed the model of the atom over time. · The modern atomic theory is called the Quantum Mechanical Model.	<u>Knowledge</u> Major insights regarding the atomic model of the atom and principal scientists include · particles – Democritus · first atomic theory of matter – John Dalton · discovery of the electron – J. J. Thompson · discovery of the nucleus – Rutherford · discovery of charge of electron – Millikan · planetary model of atom – Neils Bohr · periodic table – Mendeleev · quantum of energy – Planck · uncertainty principle – Heisenberg · wave theory – de Broglie.

Standard CH.3 a, b, c, d

The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include

- nomenclature;
- balancing chemical equations;
- writing chemical formulas—molecular, structural, empirical, and Lewis diagrams; and
- bonding types—ionic, covalent.

Essential Understandings	Essential Knowledge and Skills
· IUPAC system is used for naming compounds. · Conservation of matter is represented in balanced chemical equations. · Chemical formulas are used to represent compounds. · Subscripts represent the relative number of each type of atom in a molecule or formula unit. · A coefficient is a quantity that precedes a reactant or product symbol or formula in a chemical equation and indicates the relative number of particles involved in the reaction. · Bonds form between atoms to achieve stability.	**Knowledge** · When pairs of elements form two or more compounds, the masses of one element that combine with a fixed mass of the other element form simple, whole-number ratios (Law of Multiple Proportions). · The empirical formula shows the simplest whole-number ratio in which the atoms of the elements are present in the compound. · The molecular formula shows the actual number of atoms of each element in one molecule of the substance. · Structural formulas also show the arrangements of atoms and bonds. · Covalent bonds involve the sharing of electrons.

Standard CH.3 a, b, c, d (continued)

Essential Understandings	Essential Knowledge and Skills
	· Ionic bonds involve the transfer of electrons. · Ionization energy is the energy required to remove the most loosely held electron from a neutral atom. Elements with low ionization energy form ions easily. · Electronegativity is the measure of the attraction of an atom for electrons in a covalent bond. · Polar molecules result when a molecule behaves as if one end were positive and the other end negative. **Skills** · Name binary compounds using the Stock system (Roman numerals). · Predict, draw, and name molecular shapes (linear, bent, trigonal planar, tetrahedral). · Write equations, determine formulas, and balance chemical equations. · Know the chemical formulas for certain common substances (water, carbon monoxide, carbon dioxide, sulfur dioxide, and carbon tetraflouride). · Draw Lewis Dot Diagrams to show covalent bonding.

Standard CH.3 e, f, g

The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include

- reaction types—synthesis, decomposition, single and double replacement, oxidation-reduction, neutralization, nuclear, exothermic and endothermic, spontaneous/non-spontaneous, dissociation ionization;
- physical and chemical equilibrium; and
- reaction rates and kinetics: activation energy, catalysis, degree of randomness.

Essential Understandings	Essential Knowledge and Skills
· Elements and compounds react in different ways. · Spontaneous reactions may be fast or slow. · Randomness (entropy), heat content (enthalpy), and temperature affect spontaneity. · A reaction is said to reach equilibrium when the forward reaction rate equals the reverse reaction rate. · Reaction rates/kinetics are affected by activation energy, catalysis, and the degree of randomness (entropy).	**Knowledge** · Major types of chemical reactions are · synthesis **(A+B → AB)** · decomposition **(BC → B+C)** · single replacement **(A+BC → B+AC)** · double replacement **(AC+BD → AD+BC).** · Chemical reactions based on the net heat energy are exothermic reaction (heat producing) and endothermic reaction (heat absorbing). · Reactions can occur in two directions simultaneously. · Le Chatelier's Principle indicates the qualitative prediction of direction of change with temperature, pressure, and concentration.

Standard CH.3 e, f, g (continued)

Essential Understandings	Essential Knowledge and Skills
	· Catalysts decrease the amount of activation energy needed. **Skills** Recognize equations for redox reactions, neutralization reactions, and nuclear reactions.

Standard CH.4 a, b

The student will investigate and understand that quantities in a chemical reaction are based on molar relationships. Key concepts include

- Avogadro's principle, molar volume; and
- stoichiometric relationships.

Essential Understandings	Essential Knowledge and Skills

· Atoms and molecules are too small to count by usual means.
· A mole is a way of counting any type of particle (atoms, molecules, and formula units).
· Stoichiometry involves quantitative relationships.
· Stoichiometric relationships are based on mole quantities in a balanced equation.
	Knowledge
	· Avogadro's number = 6.02 X 10^{23} particles per mole.
	· Molar volume = 22.4 dm^3/mole and/or 22.4 L/mole for any gas at STP.
	· Total grams of reactant(s) = total grams of product(s).
	Skills
	· Make calculations involving the following relationships
	  · mole-mole
	  · mass-mass
	  · mole-mass
	  · mass-volume
	  · mole-volume

	· volume-volume · particle-particle. · Identify the limiting reactant (reagent) in a reaction. · Calculate percent yield of a reaction.

Standard CH.4 c, d, e, f

The student will investigate and understand that quantities in a chemical reaction are based on molar relationships. Key concepts include

- partial pressure;
- gas laws;
- solution concentrations; and
- chemical equilibrium.

Essential Understandings	Essential Knowledge and Skills
· Gases have mass and occupy space. · Gas particles are in constant, rapid, random motion and exert pressure as they collide with the walls of their containers. · Gas particles are separated from each other by relatively large distances. · An Ideal Gas does not exist, but this concept is used to model gas behavior. · A Real Gas exists, has intermolecular forces and particle volume, and can change states. · Equal volumes of gases at the same temperature and pressure contain an equal number of particles.	**Knowledge** · The pressure and volume of a sample of a gas at constant temperature are inversely proportional to each other (Bolye's Law). · At constant pressure, the volume of a fixed amount of gas is directly proportional to its absolute temperature (Charles' Law). · The sum of the partial pressures of all the components in a gas mixture is equal to the total pressure of a gas mixture (Dalton's Law of Partial Pressure). · Ideal Gas Law states that PV = nRT. · Molarity = moles/dm^3 and/or moles/L of solution. · Solvents can be solids, liquids, or gases.

Standard CH.4 c, d, e, f (continued)

Essential Understandings	Essential Knowledge and Skills
· A solution is a solute dissolved in a solvent. · Concentration is the amount of solute in moles divided by the number of liters of solution.	· Pressure Units include K Pa and mm of Hg. **Skills** Solve problems and interpret graphs involving all gas laws.

Standard CH.4 g

The student will investigate and understand that quantities in a chemical reaction are based on molar relationships. Key concepts include

· acid/base theory: strong/weak electrolytes, dissociation/ionization (pH, pOH), and titration.

Essential Understandings	Essential Knowledge and Skills
· Two important classes of compounds are acids and bases. · Acids and bases are defined by several theories. · Acids and bases dissociate in varying degrees.	**Knowledge** · Arrhenius acids are characterized by their sour taste, low pH, and the fact that they turn litmus paper red. Arrhenius bases are characterized by their bitter taste, slippery feel, high pH, and the fact that they turn litmus paper blue. · Bronsted-Lowry-acids are proton donors; whereas, bases are proton acceptors. · $2H_2O_{(l)} <-> H_3O^+ + OH^-$ · pH is the number that denotes hydrogen (hydronium) ion concentration. · pOH is the number that denotes hydroxide ion concentration. · pH + pOH = 14

Standard CH.4 g (continued)

Essential Understandings	Essential Knowledge and Skills
	· Strong acid-strong base titration is the process that measures [H+] and [OH-]. · Indicators show color changes at certain pHs. · Strong electrolytes dissociate completely. · Weak electrolytes dissociate partially.

Standard CH.5 a, b, c

The student will investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles. Key concepts include

- pressure, temperature, and volume;
- vapor pressure; and
- partial pressures.

Essential Understandings	Essential Knowledge and Skills
· Atoms and molecules are in constant motion. · The Kinetic Molecular Theory is a model for predicting and explaining gas behavior. · Forces of attraction between molecules determine the physical changes of state. · Vapor pressure is a property of a substance determined by intermolecular forces.	**Knowledge** · Pressure, temperature, and volume changes can cause a change in physical state. · Forces of attraction include hydrogen bonding, dipole-dipole attraction, and van der Waals forces.

Standard CH.5 d, e, f, g, h

The student will investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles. Key concepts include

- phase changes;
- molar heats of fusion and vaporization;
- specific heat capacity;
- solutions; and
- colligative properties.

Essential Understandings	Essential Knowledge and Skills
· Solid, liquid, and gas phases of a substance have different energy content. · Specific amounts of energy are absorbed or released during phase changes. · Specific heat capacity is a property of a substance. · Solutions can exist in any state or combination of states. · Polar substances dissolve ionic or polar substances; nonpolar substances dissolve nonpolar substances. · The number of solute particles changes the freezing point and boiling point of a pure substance.	**Knowledge** · Solutions can be solute/solvent, gas/gas, gas/liquid, liquid/liquid, solid/liquid, gas/solid, liquid/solid, and solid/solid. · Boiling point of liquids is affected by changes in atmospheric pressure. · Freezing point of liquids is affected by the presence of certain solutes. **Skills** · Graph and interpret a heating curve (temperature vs. time). · Calculate energy changes using specific heat capacity.

Standard CH.5 d, e, f, g, h (continued)

Essential Understandings	Essential Knowledge and Skills
	· Calculate energy changes using molar heat of fusion and molar heat of vaporization. · Interpret a phase diagram of water. · Perform calorimetry calculations. · Recognize polar molecules and non-polar molecules.

Standard CH.6 a, b, c

The student will investigate and understand how basic chemical principles relate to other areas of chemistry. Key concepts include

- organic and biochemistry*;
- nuclear chemistry; and
- environmental chemistry.

*The topics of organic and biochemistry may appear in content in other questions, but will not be tested or reported separately.

Essential Understandings	Essential Knowledge and Skills
· Organic chemistry is the study of compounds containing carbon. · Carbon atoms can form bonds with other carbon atoms. · Molecules of alkanes, alkenes, and alkynes are named using a prefix to describe the length of the carbon chain. · Biochemistry is the study of chemistry that occurs in living organisms. · Nuclear chemistry is a study of changes in the composition of the nucleus of an atom.	**Knowledge** · Alkanes have single bonds and are saturated hydrocarbons; alkenes have a double bond(s) and are unsaturated; alkynes have a triple bond(s) and are unsaturated. · Functional groups determine the properties of carbon compounds. · The beneficial uses of radioisotopes include medical diagnosis and treatment and dating ancient materials. **Skills** · Determine the half-life of a radioactive substance. · Describe alpha, beta, and gamma radiation with respect to penetrating power and composition.

Standard CH.6 a, b, c (continued)

Essential Understandings	Essential Knowledge and Skills

· Environmental chemistry is a study of chemical changes that affect the atmosphere, water, and surface of the earth.	· Define fusion and fission.
	· Delineate causes and environmental issues surrounding
	  · nuclear waste disposal
	  · radon
	  · acid rain
	  · ozone depletion
	  · global warming.

Science Standards of Learning

Teacher Resource Guide

Physics

Commonwealth of Virginia
Department of Education
Richmond, Virginia
2000

Standard PH.1 a, b, e

The student will investigate and understand how to plan and conduct investigations in which

- the components of a system are defined;
- instruments are selected and used to extend observations and measurements of mass, volume, temperature, heat exchange, energy transformations, motion, fields, and electric charge; and
- the limitations of the experimental apparatus and design are recognized.

Essential Understandings	Essential Knowledge and Skills
· Appropriate instruments are used to measure displacement, time, mass, volume, temperature, heat exchange, energy transformations, motion, fields, and electric charge. · No measurement is complete without a statement about its exactness.	**Knowledge** The difference between the accepted value and the measured value is the uncertainty or error. **Skills** · Determine percent error from experimental and theoretical values. · Measure displacement, time, mass, volume, temperature, heat exchange, energy transformations, motion, and electric charge. · Follow safe practices in all laboratory procedures.

Standard PH.1 c, d, f, g

The student will investigate and understand how to plan and conduct investigations in which

- information is recorded and presented in an organized format;
- metric units are used in all measurements and calculations;
- the limitations of measured quantities through the appropriate use of significant figures or error ranges are recognized; and
- data gathered from non-SI instruments are incorporated through appropriate conversions.

Essential Understandings	Essential Knowledge and Skills
· Experimental records, including experimental diagrams, data, and procedures, are kept concurrently with experimentation. · Tables and graphs are used to interpret, organize, and clarify experimental observations, possible explanations, and models for phenomena being observed.	**Knowledge** · Measurements are always recorded with appropriate SI units. · Calculations are made using appropriate SI units. · Results of calculations or analysis of data is reported in appropriate numbers of significant digits. · Data is organized into tables and graphed when involving dependent and independent variables.

Standard PH.2 a, b, c, d, e

The student will investigate and understand how to analyze and interpret data. Key concepts include

- a description of a physical problem is translated into a mathematical statement in order to find a solution;
- relationships between physical quantities are determined using the shape of a curve passing through experimentally obtained data;
- the slope of a linear relationship is calculated and includes appropriate units; and
- interpolated, extrapolated, and analyzed trends are used to make predictions.

Essential Understandings	Essential Knowledge and Skills
· Mathematics is a tool used to explain and describe phenomena. · Dimensional analysis is the verification of the appropriateness of the units. (This can be used as a consistency check in calculations as well as in experiments.) · Graphing is used to reveal relationships and important features of data. · Predictions are made from trends based on the data. · All experimental data does not follow a linear relationship.	**Knowledge** · The shape of the curve is used to determine the relationship of the plotted quantities. · A physical phenomena or events can often be described in mathematical terms (an equation or inequality). **Skills** · Recognize linear and non-linear relationships from graphed data. · Draw the appropriate straight line through a set of experimental data points and determine the slope with appropriate SI units. · Use dimensional analysis to solve problems.

Standard PH.2 e, f

The student will investigate and understand how to analyze and interpret data. Key concepts include

- inferential statistical tests are applied in evaluating experimental data; and
- analysis of systems employs vector quantities utilizing trigonometric and graphical methods.

Essential Understandings	Essential Knowledge and Skills
· The average for a set of data is a valid way to estimate the true value. · The spread in the set of data is an indication of the error in the measurement (a large spread indicates a large error and a small spread indicates a small error).	**Skills** · Calculate average values and compare to theoretical values. Determine percent error. · Combine vectors and resolve vectors into components using graphical methods that place scaled vectors head-to-tail. · Sketch vector diagrams and trigonometrically solve for the components. · Sketch the components of a vector and trigonometrically solve for the resultant.

Standard PH.3 a, b, c

The student will investigate and understand how to demonstrate scientific reasoning and logic. Key concepts include

- analysis of primary sources to develop and refine research hypotheses;
- analysis of how science explains and predicts relationships; and
- evaluation of evidence for scientific theories and how new discoveries may either modify existing theories or result in establishing a new paradigm.

Essential Understandings	Essential Knowledge and Skills
· Experimentation may support a hypothesis, falsify it, or lead to new discoveries. · The hypothesis may be modified based upon data and analysis. · A careful study of prior reported research is a basis for the formation of the research hypothesis. · A theory is a comprehensive and effective explanation of a set of phenomena, which is well supported by experimentation and observation.	**Knowledge** · Relativity and quantum mechanics are recent examples of paradigm shifts in theoretical physics. · The change from an earth-centered to a sun-centered model of the solar system is an example of a paradigm shift.

Standard PH.4 a, b

The student will investigate and understand how applications of physics affect the world. Key concepts include

· principles with examples from the real world; and
· exploration of the roles and contributions of science and technology.

Essential Understandings	Essential Knowledge and Skills
Physics discoveries, both theoretical and experimental, result in advancements in communication, medicine, transportation, commerce, exploration, and technology.	**Knowledge** Journals, books, Internet, and other sources are used in order to identify key contributors and contributions to physics and their impact on the real world.

Standard PH.5 a, b, c

The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. Key concepts include

- linear motion;
- uniform circular motion; and
- curvilinear motion.

Essential Understandings	Essential Knowledge and Skills

· Linear motion graphs include
  · displacement (d) vs. time (t)
  · velocity (v) vs. time (t)
  · acceleration (a) vs. time (t).
· Position, displacement, velocity, and acceleration are vector quantities.
· The concept of motion is described in terms of position, displacement, velocity, acceleration, and their dependence on time.
· Graphical analysis is used as a representation of motion.
· Horizontal and vertical components of the motion of a projectile are independent of one another.
	Knowledge
	· Velocity is the change in distance divided by the change in time.
	· A straight-line, position-time graph indicates constant velocity.
	· A straight-line, velocity-time graph indicates constant acceleration.
	· A horizontal line, velocity-time graph indicates zero acceleration.
	· The slope of a distance-time graph is the velocity.
	· The slope of a velocity-time graph is the acceleration.
	· Acceleration is the change in velocity divided by the change in time.

Standard PH.5 a, b, c (continued)

Essential Understandings	Essential Knowledge and Skills
· In a uniform vertical gravitational field with negligible air resistance, a projectile moves with constant horizontal velocity and constant vertical acceleration. · An object moving uniformly along a circle moves with a constant speed and with acceleration directed toward the center of the circle. · Centripetal force is a "true" force acting on a body in circular motion while centrifugal force is a "false" force that describes the feeling experienced in centripetal acceleration.	**Skills** · Construct and analyze displacement (d) vs. time (t), velocity (v) vs. time (t), and acceleration (a) vs. time (t) graphs. · Solve problems involving displacement, velocity, acceleration, and time in one and two dimensions (only constant acceleration). · Resolve vector diagrams involving distance and velocity. · Draw vector diagrams of a projectile's motion. Find range, trajectory, height of the projectile, and time of flight (uniform field, no air resistance). · Distinguish between centripetal and centrifugal force.

Standard PH.5 d, e, f

The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. Key concepts include

- Newton's laws of motion;
- gravitation; and
- celestial mechanics.

Essential Understandings	Essential Knowledge and Skills
· Newton's three laws of motion are the basis for understanding the mechanical universe. · Newton's Law of Universal Gravitation describes the force that determines the motion of celestial objects. · The total force on a body can be represented as a vector sum of constituent forces.	**Knowledge** · An object with no force acting on it moves with constant velocity. · The acceleration of a body is directly proportional to the net force on it and inversely proportional to its mass. · When one object exerts a force on a second object, the second exerts a force on the first that is equal in magnitude but opposite in direction. · Weight is the gravitational force acting on a body. · ($F_w = mg$) · Friction is a force that acts in a direction opposite the velocity. · For small angles of oscillation, a pendulum exhibits simple harmonic motion.

Standard PH.5 d, e, f (continued)

Essential Understandings	Essential Knowledge and Skills
	· Newton's Law of Universal Gravitation can be used to determine the force between objects separated by a known distance, and the distance between objects with a known gravitational attraction. **Skills** · Qualitatively explain motion in terms of Newton's Laws. · Solve problems involving force (F), mass (m), and acceleration (a). · Solve problems related to free-falling objects including 2-D motion. · Solve problems using Newton's Law of Universal Gravitation · Solve problems using the coefficient of friction. · Solve problems involving multiple forces using free body diagrams.

Standard PH.5 g

The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. Key concepts include

· work, power, energy.

Essential Understandings	Essential Knowledge and Skills
· Energy is the capacity to do work. Work and energy are expressed in the same units, but are not identical. · When work is done, energy converts from one form to another and energy is conserved.	**Knowledge** · Work is the product of the force exerted on an object and the distance the object moves in the direction of the force. · Power is the rate of doing work. **Skills** Solve problems involving work, power, and energy.

Standard PH.6 a, b

The student will investigate and understand that quantities including mass, energy, momentum, and charge are conserved. Key concepts include

- kinetic and potential energy; and
- elastic and inelastic collisions.

Essential Understandings	Essential Knowledge and Skills
· Kinetic energy is energy of motion. · Potential energy is energy due to an object's position or state. · For elastic collisions, total momentum and total kinetic energy are conserved. · For inelastic collisions, total momentum is conserved and some kinetic energy is transformed to other forms of energy such as heat. · Quantities such as energy and momentum are conserved when they are exchanged or transformed, and their total remains the same.	**Skills** · Calculate potential and kinetic energy from theoretical and experimental situations. · Model conservation of energy and momentum using elastic and inelastic collisions.

Standard PH.6 c

The student will investigate and understand that quantities including mass, energy, momentum, and charge are conserved. Key concepts include

· electric power and circuit design.

Essential Understandings	Essential Knowledge and Skills
Electrical charge moves through electrical circuits and is conserved.	**Knowledge** · Electric power (watt) is change in electrical energy divided by corresponding change in time. · Current (ampere) is the amount of charge that moves through a circuit element divided by the elapsed time. · Electric potential difference (voltage) is change in electric potential energy per unit charge. · In any system of electrical charge, electrical movement, or electrical interaction, both charge and energy are conserved.

Standard PH.7

The student will investigate and understand that the kinetic molecular theory can be applied to solve quantitative problems involving pressure, volume, and temperature.

Essential Understandings	Essential Knowledge and Skills
· The thermal energy of an object is the sum of the potential and kinetic energies of the internal motion of the particles. · The ideal gas model relates pressure, volume, and temperature to the number of molecules and their motion.	**Knowledge** · Heat is not the same as temperature. · In the SI system, heat is measured in joules. · In the SI system, temperature is measured in kelvins. **Skills** · Identify and relate the Celsius (C) and Kelvin (K) temperature scales. · Solve problems using the ideal gas law.

Standard PH.8 a, b

The student will investigate and understand that energy can be transferred and transformed to provide usable work. Key concepts include

- transformation of energy among forms, including mechanical, thermal, electrical, gravitational, chemical , and nuclear; and
- efficiency of systems.

Essential Understandings	Essential Knowledge and Skills
· Energy can be transformed from one form to another. (Example: Falling water turns turbines, which generates electricity and produces heat and light in a classroom.) · Efficiency of a machine is the ratio of output work to input work.	**Skills** · Illustrate that energy can be transferred from one form to another using examples from everyday life and technology. · Calculate efficiency by identifying the useful energy in a process. · Qualitatively identify the various forms of energy transformations in simple demonstrations.

Standard PH.9 a

The student will investigate and understand how to use models of transverse and longitudinal waves to interpret wave phenomena. Key concepts include

· wave characteristics (period, wavelength, frequency, amplitude, and phase).

Essential Understandings	Essential Knowledge and Skills
· Mechanical waves transport energy as a traveling disturbance in a medium. · In a transverse wave, particles of the medium move in a direction perpendicular to the direction the wave travels. · In a longitudinal wave, particles of the medium move in a direction parallel to the direction the wave travels. · For harmonic waves, velocity equals the product of the frequency and the wavelength. · Frequency and period are reciprocals of each other.	**Skills** · Identify examples of longitudinal and transverse waves. · Differentiate between transverse and longitudinal waves using simple models (slinky, stadium waves). · Illustrate period, wavelength, and amplitude on a graphic representation of a harmonic wave. · Solve problems involving frequency, period, wavelength, and velocity. · Distinguish between waves that are in-phase and out-of-phase.

Standard PH.9 b, c

The student will investigate and understand how to use models of transverse and longitudinal waves to interpret wave phenomena. Key concepts include

- fundamental wave processes (reflection, refraction, diffraction, interference, standing waves, polarization, Doppler effect); and
- light and sound in terms of wave models.

Essential Understandings	Essential Knowledge and Skills
· Waves are reflected and refracted when they encounter a change in medium or a boundary. · The overlapping of two or more waves results in constructive or destructive interference. · Polarizing filters can transmit one direction of polarized light and block the other. · When source and observer are in relative motion, a shift in frequency occurs (Doppler shift). · Sound is a longitudinal wave that travels through matter. · Light is an electromagnetic wave (transverse) that can travel through matter as well as a vacuum.	**Knowledge** · Reflection is the change of direction of the wave in the original medium. · Refraction is the change of direction (bending) of the wave in the new medium. · Diffraction is the spreading of a wave around a barrier or an aperture. · The pitch of a note is determined by the frequency of the sound wave. · The color of light is determined by the frequency of the light wave. · As the amplitude of a sound wave increases, the loudness of the sound increases.

	· As the amplitude of a light wave increases, the brightness of the light increases.

Standard PH.9 b, c (continued)

Essential Understandings	Essential Knowledge and Skills
	Skills · Graphically illustrate reflection and refraction of a wave when it encounters a change in medium or a boundary. · Graphically illustrate constructive and destructive interference. · Identify a standing wave on a string.

Standard PH.10 a, b

The student will investigate and understand that different frequencies and wavelengths in the electromagnetic spectrum are phenomena ranging from radio waves through visible light to gamma radiation. Key concepts include

· properties and behaviors of radio, microwaves, infra-red, visible light, ultra-violet, X-rays, and gamma rays; and
· current applications based on the wave properties of each band.

Essential Understandings	Essential Knowledge and Skills
Frequency, wavelength, and energy vary across the entire electromagnetic spectrum.	**Knowledge** · The long wavelength, low frequency portion of the electromagnetic spectrum is used for communication (e.g., radio, TV, cellular phone). · Medium wavelengths (infra-red) are used for heating and night vision enhancing devices. · Visible light comprises a very narrow portion of the electromagnetic spectrum. · Ultra-violet wavelengths (shorter than the visible spectrum) are responsible for sunburn. · X-rays and gamma rays are the highest frequency, shortest wavelength, and primarily used for medical purposes.

Standard PH.11 a, b

The student will investigate and understand how light behaves in the fundamental processes of reflection, refraction, and image formation in describing optical systems. Key concepts include

- application of the laws of reflection and refraction; and
- construction and interpretation of ray diagrams.

Essential Understandings	Essential Knowledge and Skills
· The ray model of light can be used to understand the behavior of optical systems. · Light incident on a smooth plane surface is reflected such that the angle of incidence equals the angle of reflection. · Light incident on a smooth surface is refracted (transmitted) in such a manner that the ratio of the sine of the angle of incidence and the sine of the angle of refraction equals a constant.	**Knowledge** · For a converging lens, the focal point is the point at which a beam of light parallel to the principal axis converges. · For a diverging lens, the focal point is the point from which a beam of light parallel to the principal axis appears to originate. · A real image is formed by converging lights rays and can be displayed on a screen. · A virtual image can be seen by an observer but cannot be projected on a screen because the light does not actually emanate from the image. · The focal point is the point at which rays converge or from which they appear to diverge in a lens or mirror.

Standard PH.11 a, b (continued)

Essential Understandings	Essential Knowledge and Skills
	· The index of refraction is the ratio of the speed of light in a vacuum to the speed of light in the medium. **Skills** · Investigate propagation, refraction, and reflection using the ray model of light. · Construct ray diagrams to verify the laws of reflection and refraction.

Standard PH.11 c, d

The student will investigate and understand how light behaves in the fundamental processes of reflection, refraction, and image formation in describing optical systems. Key concepts include

· development and use of mirror and lens equations; and
· predictions of types, size, and position of real and virtual images.

Essential Understandings	Essential Knowledge and Skills
The mirror and thin lens equation can be used to calculate the position of the object or image based on the focal length of the mirror or lens.	**Skills** · Solve problems dealing with object and image distance, object and image size, and focal length using the lens and mirror equations. · Illustrate characteristics of a real and a virtual image using examples (lens and mirrors). · Identify the type of image (real, virtual, and size) formed by convex mirrors and by concave mirrors when the object is located at varying locations (inside the focal point, at the focal point, at twice the focal point, and beyond twice the focal point). · Identify the type of image (real, virtual, and size) formed by concave lens and by convex lens when the object is located at varying locations (inside the focal point, at the focal point, at twice the focal point, and beyond twice the focal point).

Standard PH.12 a, b, c, d

The student will investigate and understand how to use the field concept to describe the effects of electric, magnetic, and gravitational forces. Key concepts include

- inverse square laws;
- Newton's law of universal gravitation;
- Coulomb's law; and
- operating principles of motors, generators, and cathode ray tubes.

Essential Understandings	Essential Knowledge and Skills
· The force found from Newton's Law and Coulomb's Law is dependent on the inverse square of the distance between two objects. · The electrostatic force (Coulomb's Law) can be either repulsive or attractive, depending on the sign of the charges. · The gravitational force (Newton's Law) is always an attractive force. · The interaction of two particles can be described as a two step process: the creation of a field by one of the particles and the interaction of the field with the second particle.	**Knowledge** · Newton's Law of Universal Gravitation: Every particle in the universe attracts every other particle in the universe. $F = G (m_1m_2)/r^2$. (F is the force, G is the universal gravitation constant, m is the mass of the two particles, and r is the distance between them.) · Coulomb's Law: The magnitude F of the electrostatic force exerted by one point charge on another point charge is directly proportional to the magnitudes of q1 and q2 of the charges and inversely proportional to the square of the distance r between them: $F = k (q_1q_2)/r2$. · The rotation of the coil of a motor or a generator through a magnetic field is used to transfer energy.

Standard PH.13 a, b

The student will investigate and understand how to diagram and construct basic electrical circuits and explain the function of various circuit components. Key concepts include

- Ohm's law; and
- series, parallel, and combined circuits.

Essential Understandings	Essential Knowledge and Skills
· Current is the flow of electrical charge. · Voltage in a circuit provides the energy that drives the current. · Elements in a circuit are positioned relative to other elements either in series or parallel.	**Knowledge** · According to Ohm's Law, the resistance equals the voltage divided by the current. · Voltage difference is change in electrical potential energy per unit charge. **Skills** · Recognize a series and a parallel circuit. · Apply Ohm's law to a series and a parallel circuit. · Assemble simple circuits composed of batteries and resistors in series and in parallel. · Solve simple circuits using Ohm's Law.

Standard PH.14 a, b, c, d

The student will investigate and understand that extremely large and extremely small quantities are not necessarily described by the same laws as those studied by Newtonian physics. Key concepts include

- wave/particle duality;
- wave properties of matter;
- matter/energy equivalence; and
- quantum mechanics and uncertainty.

Essential Understandings	Essential Knowledge and Skills
· For processes that are important on the atomic scale, objects exhibit both wave characteristics (e.g., interference) as well as particle characteristics (e.g., discrete amounts, and fixed definite number of electrons per atom). · The special theory of relativity predicts that energy and matter can be converted into each other.	**Knowledge** · Electrons rotating around the nucleus of an atom can be treated as standing waves in order to model the atomic spectrum. · The dramatic examples of the mass-energy transformation are the fusion of hydrogen in the sun, which provides light and heat for the earth, and the fission process in nuclear reactors that provide electricity. · Quantum mechanics requires an inverse relationship between the measurable location and the measurable momentum of a particle. The more accurately one determines the position of a particle, the less accurately the momentum can be known, and vice versa. This is known as the Heisenberg uncertainty principle.

Standard PH.14 e, f, g, h. i

The student will investigate and understand that extremely large and extremely small quantities are not necessarily described by the same laws as those studied in Newtonian physics. Key concepts include

- relativity;
- nuclear physics;
- solid state physics;
- superconductivity; and
- radioactivity.

Essential Understandings	Essential Knowledge and Skills
· The motion of objects traveling near or approaching the speed of light does not follow Newtonian Mechanics but must be treated within the theory of relativity. · Nuclear physics is the study of the interaction of the protons and neutrons in the atom's nucleus. · Natural radioactivity is the spontaneous disintegration of unstable nuclei. · Atoms and molecules bind together in regular arrays to form crystals. The structure of these crystals is important in determining the properties of these materials (appearance, hardness, etc.). · Certain materials at very low temperatures exhibit the property of zero resistance called superconductivity.	**Knowledge** · Objects cannot travel faster than the speed of light. · The nuclear force binds protons and neutrons in the nucleus. · Alpha, beta, and gamma are different emissions associated with radioactive decay. · Fission is the breakup of heavier nuclei to lighter nuclei. · Fusion is the combination of lighter nuclei to heavier nuclei. · Many substances in the natural world have a crystal structure, including most metals and minerals.
